METHODS AND SYSTEMS FOR EFFICIENTLY PROCESSING IMAGE DATAFOR REPRODUCTION

Field of the Invention

The current invention is generally related to methods of and systems for image reproduction, and more particulary related to the methods of and the systems for approximating or compressing color data prior to color image processing in order to efficiently reproduce an original color image.

BACKGROUND OF THE INVENTION

In a digital color copier, various components perform a series of processes in order to reproduce an original image as shown in FIGURE 1. In general, the processes initially involve scanning an original image 1 in red, green and blue (RGB) values in an analog format via an optical scanner unit 2. An analog-to-digital (A/D) converter 3 converts the scanned analog signal into digital signal. Since each scanner 2 has its own input characteristics, a scanner correction unit 4 corrects the digital data according to the input characteristics. For the output purpose, the corrected digital signal is converted into cyan, magenta, yellow , and black (CMYK) signals by a color conversion unit 5. An image processing unit 6 further processes the CMYK sigmals. For example, the image processing involves enlargement, reduction and cutting a certain portion of the image. Prior to

outputting an image, an intensity gamma correction unit corrects the intensity level according to the output characteristics of an output unit 9. Similarly, a chromaticity gamma correction unit 8 also corrects the chromaticity values according to the output characteristics of the output unit 9 prior to outputting an image.

In the above described digital reproduction processes, an amount of color information is an important factor in determining the speed of each process. For example, assuming that each pixel is represented by 32-bit data for the CMYK value (8-bit for each color component C, M, Y or K), at 400 dpi, the total amount of data representing an image on A-4 size paper is approximately 62 mega bytes (MB). In order to reproduce ten pages of A-4 color image per minute (10 ppm), 10.3 MB of information must be processed each second. In other words, referring back to FIGURE 1, the units such as the image processing unit 6 must be able to process information faster than at least 10.3 MB/sec. In general, because of the above required high performance, certain crucial processing components are costly and cannot be replaced with less expensive slow units.

One approach to use the slow processing components is to reduce an amount of data by conventional data compression techniques. In general, the conventional data compression techniques are used to reduce the amount of data prior to storing in a storage device so that the storage space is saved. In another area of applications, the conventional data compression techniques are useful to reduce the data size prior to transmitting the data in order to the save transmission line capacity. However, since the compressed data generally contains less than original information, the compressed data needs to be restored to the original uncompressed data via a decompression process before the data is image processed. In other words, the compressed data is

not usually suitable for image processing such as enlargement and reduction. For this reason, the conventional compression techniques are not particularly useful for efficiently processing image data.

Another approach in reducing the data size is approximation of the original data. Since the ability of humans to differentiate the gradation values rapidly decreases as the resolution of the output image increases, at a high resolution, the gradation appears indistinguishable to human eyes. P.G. Loetling, visual Performance and Image Coding, SPIE/OSA, Image Processing 74 (1976). The input color data is approximated by a fixed reduction rate using an error diffusion method or a dithering method. For example, Japanese Patent applications 2-210963 and 6-98157 disclose improved error diffusion techniques. However, these approximation techniques are applied to approximate the input data only for the purpose of outputting the input image.

As described above, there has been a need for efficiently image processing a large amount of information such as color image data without relying upon expensive high speed processing components without sacrificing the reproduction speed and reproduced image quality. In the alternative, there has been also a need for improving the processing speed without requiring a higher speed image processing components.

SUMMARY OF THE INVENTION

To solve the above and other problems, according to the current invention, a method of color image processing based upon compressed data, includes the steps of: a) inputting original image data including pixel color values represented by a first number of color values in an original image; b) approximating the pixel color values based upon a

second number of color values so as to generate approximated
color image data, the second number being smaller than the
first number; c) processing the approximated color image data
so as to generate processed approximated color image data;
and
d) outputting a reproduced image based upon the processed
approximated color image data.

According to a second aspect of the current invention,
a method of efficiently reproducing color image, includes the
steps of: a) compressing pixel color values into compressed
color image data representing a smaller number of colors than
original number of colors in an input image; b) image
processing the compressed color image data to generate
processed compressed data; c) converting the processed
compressed data to output processed color image data; and
d) reproducing an image based upon the output processed color
image data.

According to a third aspect of the current invention,
a system for color image processing based upon compressed
data, includes: an input unit for converting an original
image into pixel color values representing a first number of
colors; an approximation unit connected to the input unit for
approximating the pixel color values into approximated color
image data representing a second number of colors, the second
number being smaller than the first number; a processing unit
connected to the approximation unit for processing the
approximated color image data so as to generate processed
approximated color image data; and an output unit connected
to the processing unit for outputting an image based upon the
processed approximated color image data.

According to a fourth aspect of the current invention,
a system for efficiently reproducing color image, includes: a
compression unit for compressing pixel color values into
compressed color image data representing a smaller number of

colors than original number of colors in an input image; an
image processing unit connected to the compression unit for
image processing the compressed color image data to generate
processed compressed data; a conversion unit connected to the
image processing unit for converting the processed compressed
data to output processed color image data; and an output unit
connected to the conversion unit for reproducing an image
based upon the output processed color image data.

       These and various other advantages and features of
novelty which characterize the invention are pointed out with
particularity in the claims annexed hereto and forming a part
hereof. However, for a better understanding of the
invention, its advantages, and the objects obtained by its
use, reference should be made to the drawings which form a
further part hereof, and to the accompanying descriptive
matter, in which there is illustrated and described a
preferred embodiment of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

       FIGURE 1 is a block diagram illustrating components
performing steps involved in conventional digital copying.

       FIGURE 2 is a block diagram illustrating components
performing steps involved in digital copying according to the
current invention.

       FIGURES 3A and 3B are block diagrams illustrating
components performing steps involved in digital copying with
compressed data transmission according to the current
invention.

       FIGURES 4A and 4B illustrate an alternative embodiment
according to the current invention in which the compressed
data is transmitted to a second location before the
compressed data is image processed.

FIGURES 5A and 5B respectively illustrate tables respectively containing exemplary values and the corresponding weight values.

FIGURES 6A and 6B illustrate examples of thresholds values used in the compression of 8-bit data into 2-bit data.

FIGURES 7A and 7B respectively illustrate another example pair of tables containing exemplary values and the corresponding weight values.

FIGURES 8A, 8B, 8C and 8D respectively illustrate an example of a compressed image data representation, the corresponding compressed numerical representation, an example of a cut-out section in the numerical representation, and the cut-out section in the corresponding image representation.

FIGURES 9A and 9B illustrate a process performed upon the cut-out area as described in FIGURES 8.

FIGURES 10A and 10B respectively show an exemplary function and a table used in the process for correcting intensity values or decompressing intensity values.

FIGURES 11A, 11B, 11C and 11D respectively indicate one exemplary conversion function for each color component C, M, Y and K or while 11E indicates one exemplary table of conversion values for an output device.

FIGURE 12 is an alternative conversion/decompression table for the processed compressed values prior to inputting to an output device.

FIGURE 13 is a summary table comparing features of a conventional digital color copier and those of a preferrd embodiment according to the current invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT(S)

Referring now to the drawings, wherein like reference numerals designate corresponding structure throughout the

views, and referring in particular to FIGURE 2, according to
one preferred embodiment of the current invention, an optical
scanner 2 scans an original image 1 in red, green and blue
(RGB) values in an analog. An analog-to-digital (A/D)
converter 3 converts the scanned analog signal into digital
signal. Since each scanner 2 has its own input
characteristics, a scanner correction unit 4 corrects the
digital data according to the input characteristics. For the
output purpose, the corrected digital signal is converted
into cyan, magenta, yellow , and black (CMYK) signals by a
color conversion unit 5. Before an image processing unit 6
further processes the CMYK signals, an approximation unit 10
approximates the CMYK signals by a smaller size of image
information based upon a predetermined method such as an
weighted error diffusion method and a fixed ratio length
compression. According to alternative embodiment of the
current invention, a compression unit is used in place of the
approximation unit 10. Then, the image processing unit 6
further processes the approximated or compressed CMYK signals
by performing a process such as enlargement, reduction and
cutting a certain portion of the image. Prior to outputting
an image, an intensity gamma correction unit corrects the
intensity level according to the output characteristics of an
output unit 9. Similarly, a chromaticity gamma correction
unit 8 also corrects the chromaticity values according to the
output characteristics of the output unit 9 prior to
outputting an image.

　　　Still referring to FIGURE 2, one preferred embodiment
of the approximation unit 10 according to the current
invention approximates two hundred fifty-six gradations or
colors by four gradations or colors. The numbers ranging
between 0 and 255 require 8 bits of information while the
numbers ranging between 0 and 3 require only 2 bits. Since
each of the color components such as C, M, Y and K is

individually approximated for each pixel, 24 bits are saved
per pixel. The above described approximation is also known
as quaternarization. In order to quaternarize the original
8-bit density or color information, a fixed rate
approximation such as a dithering or error diffusion method
is used. As a result of approximation, the 8-bit data is
essentially compressed into 2-bit data. However, as later
will be described, the meaning of the term "compressed"
according to the current invention is distinct from the
conventional data compression technique.

The approximated data is used for the additional
processes prior to reproduce a processed original image. The
image-processing unit 6 takes advantage of quaternary data
which requires less processing than the original 8bit data
for the identical editing tasks such as enlargement,
reduction and cutting of the original image. Because of the
compressed data, the image-processing unit 6 is implemented
with an inexpensive components and meets the operational
speed requirement. In the alternative, the imageprocessing
unit 6 with high-performance components increases the
processing speed. Similarly, the intensity gamma correction
unit 7 and the chromaticity gamma correction unit 8 both use
the quaternary data for their efficient processing. The
approximated data is prepared prior to outputting a
reproduced image via the outputting unit 9.

The outputting unit 9 receives the processed
approximated data according to the current invention and
generally outputs an image with improved quality without
sacrificing resolution. Outputting devices such as printers,
digital copiers, facsimile machines outputs an image based
upon a unit dot. For example, a printer with 400 DPI and 256
gradations is designed to output an image based upon 400 dots
per inch (DPI) and 1/255th of one dot as a unit of gradation.
However, because the unit of control under the 256

gradation scheme is too small to output, the output is often
inconsistent. Even though the output data specifies the 8
bit information or 256-gradation values, the output devices
are often not sufficiently stable to generate the full range
of the 256 gradations. Consequently, the output image is not
reliably reproduced. In contrast to the above described
unreliable output scheme, the quaternary data has only four
gradations such as 0, 1, 2 and 3 as stored in two-bit
information. These two-bit information is later converted or
translated into four eight-bit values such as 0, 85, 170 and
255. Thus, the output is stable and the quaternarized
gradation appears superior to that reproduced under the 256
gradation scheme.

        Furthermore, in order to compensate for the lack of
capability of expression 256 gradations per dot, in certain
printers, a plurality of dots is used as a unit for one
pixel. As a result, the resolution of an output image is
undesirably decreased. In contrast, the resolution of the
output image is not affected under the quaternary system.
Since only four values such as 0, 1, 2 and 3 need to be
differentiated in the output of each dot, the dots do not
have to be combined and the resolution remains the same under
the quaternary system. In conclusion, when output devices
such as printers are not capable of generating the same
number of gradations as an original input image, the
preferred embodiment provides a superior results without
sacrificing resolution.

        Referring to FIGURES 3A and 3B, a second preferred
embodiment according to the current invention is generally
similar to the above described first preferred embodiment.
However, the second preferred embodiment is modularized into
a reader module as shown in FIGURE 3A and an image
processing/reproduction module as shown in FIGURE 3B. These
modules are interfaced by interfaced units 14 and 15.

Furthermore, the second preferred embodiment additionally
includes a variable length encoder units 12 and a variable
length decoder 16. After the color image information is
similarly processed in the reader module by the units 15 as
described with reference to FIGURE 2, the fixed compression
unit 10' compresses the size of the CMYK color data by
approximation. The variable length encoder unit 12 further
compresses the 2-bit data size based upon a predetermined
variable length compress technique such as bit plane JBIG
coding. The reduced-size data is then sent from the reader
module to the image processing/reproduction module via a
first interface unit 14 to a second interface unit 15. In
the image processing module, a second variable length decoder
unit 16 restores the reduced data size back to fixed 2bit
data. The processing units 6-8 processes the 2-bit data as
described with respect to FIGURE 2 before an output unit 9
outputs an image.

     Referring to FIGURES 4A and 4B, a third preferred
embodiment according to the current invention is generally
similar to the above described second preferred embodiment.
However, the third preferred embodiment is suitable for
efficiently transmitting data from one location to another.
After image information is compressed to 2bit information by
a fixed-ratio length compression unit 22 and further
compressed by a variable length encoder unit 23, the reduced
size data is transmitted through a transmission line via a
transmitting interface unit 24. A receiving interface 25
receives the transmitted data, and a second variable length
decoder unit 26 restores the reduced data size back to 2bit
data. The image-processing units 27, an intensity gamma
correction unit 28 and a chromaticity gamma correction unit
29 process the 2-bit data as described with respect to FIGURE
2 before an output unit 30 outputs an image. The above
described third preferred embodiment thus promotes not only

the efficiency of the image processing tasks but also the
efficiency of the transmission line by saving its capacity.

In the above approximation unit or compression unit, a
weighted error diffusion process is performed on the original
image data, and the error diffused data is subsequently
approximated. In general, one weighted error diffusion
technique accumulates the weighted error of each pixel
between its original input value and its output value from
the surrounding pixels. Because the output values of the
error diffusion are limited to four values, the errors
between the input values and the output values are weighted
according to a predetermined set of weights, and the weighted
errors are distributed among the neighboring pixels so as to
keep the average gradation equal to the original gradation.
In other words, the average error is tantamount to zero. The
predetermined weights are determined based upon the distance
between the current pixel and the surrounding pixel and
modified by experimentations.

In the above described error diffusion method, a set
of weight values or parameters plays an important role in
designing hardware and software. For the efficient software
and hardware design, each weight parameter value is the nth
power of 1/2 or 2 where n is an integer or the summation of
the n-th power of 1/2 or 2 where n is an integer. In
addition, the sum of the above described individual weight
parameter values must be 2^n where n is an integer. The above
described weight parameters increase the error diffusion
processing speed since the binary processor requires only
shift operations. At the same time, the above described
weight values reduce the hardware cost since they do not need
an expensive math-coprocessor.

The above described weight values also play an
important role in determining the aesthetic appearance of a

printed image. The human perception of the error diffused
image is termed as texture. Certain weight values used
during the above described error diffusion process lead to an
undesirably textured print image. The weight values as shown
in FIGURE 5B are experimentally determined to substantially
minimize the undesirable texture while optimizing the above
described processing efficiency.

Referring specifically to FIGURE 5A, pixels are
processed from left to right and from top to bottom. The
current unprocessed pixel is designated by (x,y). An
original input value of the current pixel is 30. Surrounding
pixels are designated by (x-1, y-1) through (x-1,y) and they
have been already processed for error diffusion. The values
in these error diffused pixels respectively indicate a
residual difference value. To ultimately determine the
residual difference value of the current pixel, a sum of the
product between a weight (w_i) and a residual difference value
(rd_i) is divided by the sum of the weight values (i), and the
quotient is added to the current pixel input value (cp). In
general, the above described relation is expressed by the
following equation:

$$wed_{n+1} = cp + \sum (rd_i \cdot w_i) / \sum w_i$$

where wed_{n+1} is a weighted error diffusion value for the
current pixel. The summation is taken for i from 1 to n and
n is the predetermined number of processed surrounding
pixels.

To illustrate the above described determination of the
weighted error diffusion value, referring to FIGURE 5B, the
weight values are provided for each surrounding pixel having
the residual difference values as shown in FIGURE 5A.
Applying these values to the above described equation, the

weighted error diffusion value for the current pixel is determined as follows:

$$30 + (78 \cdot 0.125 + 56 \cdot 0.25 + 43 \cdot 0.125 + 170 \cdot 0.125 + 52 \cdot 0.375)/1 \doteq 100$$

The notice that the sum of the above weights is determined to be one for convenience. The error diffusion value is now approximated before the residual difference value is determined for the current pixel.

To illustrate the approximation process, the above determined weighed error diffusion value for the current pixel is used to obtain final 2-bit information . Referring to FIGURE 6A, one preferred processes of the quaternarization process according to the current invention approximate the weighted input values by n approximated values. The range k is less than the range of the input values. According to one preferred quaternarization method, the weighted error diffused input values range from 0 to 255 while the approximated values range from 0 to 3. In other words, 8-bit information is approximated by 2-bit information, and the data size is compressed. In approximating into the four values, each weighted error diffusion value is compared against a set of predetermined threshold values to determine an approximated value. Referring to FIGURE 6A, one set of exemplary predetermined threshold values includes 43, 128 and 213. Any input values fall in a range between 0 and 43 is approximated by a quaternary value 0. Similarly, the second range is defined by thresholds 43 and 128 and assigned a quaternary value 1. Lastly, the third range is between the thresholds 128 and 213 while the fourth range is between 213 and 255. The third and fourth ranges are respectively assigned a quaternary value of 3 and 4. Thus, the current pixel error diffusion value 100 is falls between the two

thresholds between 43 and 128 and is approximated by 1 according to this exemplary threshold values.

To further illustrate the determination of the residual difference value of the above described current pixel, still referring to FIGURE 6A, the weighted error diffusion value is compared to a certain standard value referenced by the approximated value. According to one preferred embodiment, the standard value is determined to be the nearest threshold value of three equally divided ranges. In other words, the value one in the quaternary system corresponds to 85 in the 256 gradation scale. Since the error diffusion value "100" is approximated by one in the quaternary system, a residual difference value of "15" exists when "85" is outputted in the 256-gradation scale. The above newly determined residual difference value is now used for the next cycle in determining the error diffusion value for a new current pixel (x+1, y).

Referring to FIGURE 6B, another set of exemplary threshold values for the quaternary system includes 43, 110 and 190 for approximating the input values ranging from 0 to 255. Unlike the threshold values as shown in FIGURE 6A, each of the divided ranges is different in size in the 256-gradation scale.

Referring to FIGURES 7A and 7B, a second preferred process of the error diffusion is to distribute the weighted error to the surrounding pixels rather than to accumulate them from the surrounding pixel. Turning to FIGURE 7A, if the current pixel 30 at (x,y) is approximated based upon the thresholds as shown in FIGURE 6A, since 30 falls between the two threshold vales 0 and 43, 30 in the 256 gradation scale is approximated by 0 in the quaternary scale. Thus, the above described residual difference is 30. The residual difference is now distributed to surrounding pixels based upon the corresponding weights as shown in FIGURE 7B. The

sum of the weights is one to distribute the entire value of
the residual difference.

Among the five surrounding pixels from a pixel at
(x+1, y) to a pixel at (x+1, y+1), the residual difference
value 30 is distributed as follows:

(x+1, y)   : 52+30·0.375 ≒ 63

(x+2, y)   : 170+30·0.125 ≒ 174

(x-1, y+1) : 43+30·0.125 ≒ 47

(x, y+1)   : 56+30·0.25 ≒ 64

(x+1, y+1) : 78+30·0.125 ≒ 82

After the above described approximation process is
completed, referring to FIGURES 8A-D, the approximated image
data is efficiently image-processed according to the current
invention. The image processing tasks involve enlargement,
reduction and selection of a certain portion of the image.
In the following, the image selection process is illustrated
using an image represented by the quaternarized density
values . As described before, the quaternarized density
values range from 0 to 3 and respectively indicated by the
corresponding shade as shown in FIGURE 8A. FIGURE 8B shows
the same image as FIGURE 8A in the approximated data values.
 Furthermore, FIGURE 8B also illustrates a selected area to
be cut out from the image as indicated by a shaded area. The
desired area after the cutting process is illustrated in
approximated data as shown in FIGURE 8C as well as in image
as shown in FIGURE 8D.

Referring to FIGURES 9A and 9B, in order to isolate a
desired portion of the image based upon the above described
cutting process, the address of the beginning and end of each
horizontal line must be determined. In the first horizontal
line of the desired portion, the beginning address is
designated by P while the ending address is designated by Q.

Both P and Q in the following illustration are relative
address with respect to the upper left corner of the image
from which the desired portion is to be extracted. Referring
back to FIGURE 8A, the width of the image is assumed to be 16
pixels indexed from 0 to 15. Since each pixel is
approximated by 2-bit quaternarized data, each byte of
information has four pixels.

In order to determine the relative addresses P and Q
in terms of the number of bytes, the following equation is
used:

P = (the width of the image) x

    (the y coordinate of P) x 1/4 +

    (the x coordinate of P) x 1/4

Q = (the width of the image) ·

    (the y coordinate of Q)· 1/4 +

    (the x coordinate of Q)· 1/4

Applying the P=(2,2) and Q=(5,2) to the above equations, the
following number of bytes is obtained as offset address:

    P = 16 · 2 · 1/4 + 2 · 1/4 = 8 + 1/2
    Q = 16 · 2 · 1/4 + 5 · 1/4 = 9 + 1/4

The starting address P at 8 and 1/2 bytes means that eight
bytes plus 4 bits from the (0,0) origin as shown in FIGURE
9A. The 1/2 byte is into 4 bits from the most significant
bit 7 in a byte and indicates the address starts at bit 3.
Similarly, the ending address Q at 9 and 1/4 bytes means that
nine bytes plus 2 bits from the origin as shown in FIGURE 9A,
and the 1/4 byte ends at bit 4. Thus, the first
horizontal row of pixels in the selected portion to be cut
out from the original image is specified by the relative

offset addresses P and Q.   Using P and Q, the first
horizontal line containing the data "0330" is isolated.   By
the same token, the second through the fourth pixel rows of
the desired portion are specified based upon pairs of
addresses.   Although the above example involves a single set
of quaternarized data, for color representations, similar
processes are repeated for each color component.   During the
above described image-processing operations, the approximated
data allows faster and efficient data transfer and
manipulations.

     Now referring to FIGURES 10A and 10B, before the above
described image-processed approximated data is outputted via
an outputting unit, the intensity or density of the
approximated data is corrected according to the output
characteristics of the outputting unit.   Assuming that the
outputting unit such as a color printer has 100 gradations,
according to the current invention, a gamma intensity
correction unit 7 such as shown in FIGURE 2 performs a
uniform conversion of the quaternarized data to the
predetermined gradation values ranging from 0 to 99 as shown
in FIGURE 10A.   According to another preferred embodiment,
the same conversion task is efficiently accomplished by a
table-look-up process using a table as shown in FIGURE 10B.

     In addition to the above described density correction,
referring to FIGURES 11A-11E, the color data is also
corrected according to the output characteristics of the
outputting unit prior to the image reproduction.   Assuming
that the outputting unit such as a color printer has 100
gradations, according to the current invention, a gamma
chromaticity correction unit 8 such as shown in FIGURE 2
performs the conversion of the quaternarized data to the
predetermined gradation values ranging from 0 to 99 for cyan,
magenta, yellow and black as respectively shown in FIGURES

11A-11D. Notice that each color component is uniquely
converted based upon a different conversion curve. According
to another preferred embodiment, the above described same
conversion tasks are efficiently accomplished by table-look-
up processes using a single color balance table for the color
components as shown in FIGURE 11E.

Additionally, referring to FIGURE 12, the above color
balance table as shown in FIGURE 11E and the intensity table
10B are combined into one table. The above described
conversion values are only exemplary and can be altered based
upon the output characteristics of the printer and other
factors. In the above discussion of the image-processing,
the outputting unit such as a laser jet printer or an ink-jet
printer is assumed to have a less gradation capability than
the originally inputted data. For certain other high-
gradation outputting devices such as thermal dye sublimation
printers and silver halide printers, the above described
compressed or approximated data needs to be decompressed to
the original gradation level in order to take advantage of
such high-gradation capabilities.

Lastly, referring to FIGURE 13, the comparison in
color image reproduction between a conventional digital
copier and the above described preferred embodiment according
to the current invention is summarized in a table format.
For this comparison, the color image reproduction is
performed at 400 dpi of the resolution, 256 gradation scale
and 10 p.p.m. (pages per minute) using A-4 size paper. The
compression or approximation is based upon a quaternary error
diffusion method. Because of the reduced data processing
amount, the processing speed in the preferred embodiment is
approximately one fourth of that of the conventional digital
copier in order to reproduce at 10 p.p.m.. In other words,
if the processing speed of the preferred embodiment is
maintained at 10.3 MB/sec, the reproduction rate is improved.

The reproduction image quality of the preferred embodiment is also improved since the output stability is assured while the resolution is maintained as the same level.

In general, the current invention is applicable to improve color image data processing, gray scale image data processing and a combination of both during the image reproduction process. It is to be understood, however, that even though numerous characteristics and advantages of the present invention have been set forth in the foregoing description, together with details of the structure and function of the invention, the disclosure is illustrative only, and changes may be made in detail, especially in matters of shape, size and arrangement of parts, as well as implementation in software, hardware, or a combination of both within the principles of the invention to the full extent indicated by the broad general meaning of the terms in which the appended claims are expressed.